Staged hybrid approach using proximal thoracic endovascular aneurysm repair and distal open repair for the treatment of extensive thoracoabdominal aortic aneurysms

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Objective: **Repair of patients with extent I and II thoracoabdominal aortic aneurysms (TAAAs) is associated with significant morbidity and mortality, whereas repair of more distal extent III and IV TAAAs has a lower risk of paraplegia and death. Therefore, we describe an approach using thoracic endovascular aneurysm repair (TEVAR) as the index operation to convert extent I and II TAAAs to extent III and IV TAAAs amenable to subsequent open aortic repair to minimize patient risk.**

Methods: **Between July 2007 and March 2012, 10 staged hybrid operations were performed to treat one extent I and nine extent II TAAAs. Aortic aneurysm pathology included five chronic type B dissections, three acute type B dissections, and two penetrating aortic ulcers. Initially, the proximal descending thoracic aorta was repaired with TEVAR for coverage of the most proximal fenestration or penetrating ulcer, with seven elective and three emergent repairs. Interval open distal aortic replacement was performed in a short-term planned setting or for progressive dilation of the distal aortic segment. In the open repair, the proximal end of the graft was sewn directly to the distal end of the TEVAR and outer wall of the aorta.**

Results: **Average patient age was 48 years, and 60% were men. Risk factors included hypertension (80%), current tobacco use (50%), and Marfan syndrome (30%). Complications after TEVAR included type IA (n = 1) and type II (n = 3) endoleaks, pleural effusions (n = 3), and acute kidney injury (n = 1). Three patients required endovascular reinterventions. In patients with dissection, persistent filling of the false lumen was common and associated with distal thoracic aortic dilation. Complications of open repair included acute kidney injury in two patients, but no cardiac, pulmonary, or neurologic morbidity. Median time between TEVAR and open repair was 14 weeks. Most importantly, no deaths or neurologic deficits occurred after either procedure during a median follow-up of 35 weeks.**

Conclusions: **A staged hybrid approach to extensive TAAAs combining proximal TEVAR, followed by interval open distal TAAA repair, is safe and appears to be an effective alternative to traditional open repair. This approach may decrease the significant morbidity associated with single-stage open extent I and II TAAA repairs and may be applicable to multiple TAAA etiologies. (J Vasc Surg 2012;56:1495-1502.)**

Patients with untreated thoracoabdominal aortic aneurysms (TAAAs) have an estimated mortality rate of 76% after 2 years, with half of the deaths due to aortic rupture.[1] Open repair of extensive TAAAs provides definitive therapy and has improved patient outcomes; however, open repair carries a risk of death and end-organ damage, including spinal cord ischemia, pulmonary complications, and renal failure.[2-4] Outcomes of open TAAA repair vary according to the Crawford classification: repair of Crawford extent II TAAAs is associated with a higher rate of death, paraplegia, renal failure, and pulmonary complications than extent III or IV TAAAs.[2,5-7] Mortality after repair of extent II TAAAs ranges from 10% to 42%, and paraplegia/paraparesis occurs in 7% to 32% of patients.[8]

Thoracic endovascular aneurysm repair (TEVAR) has decreased aneurysm repair–related mortality and morbidity compared with open surgery (OS) for isolated thoracic aortic aneurysms.[9,10] In addition, staged procedures for open thoracic aortic surgery are associated with a decreased incidence of spinal cord ischemia.[11] Therefore, we propose a two-stage technique combining the benefits of TEVAR and staged thoracic aortic surgery for the treatment of extensive TAAAs. In the first stage, the proximal aspect of the TAAA is treated with TEVAR to convert extent II

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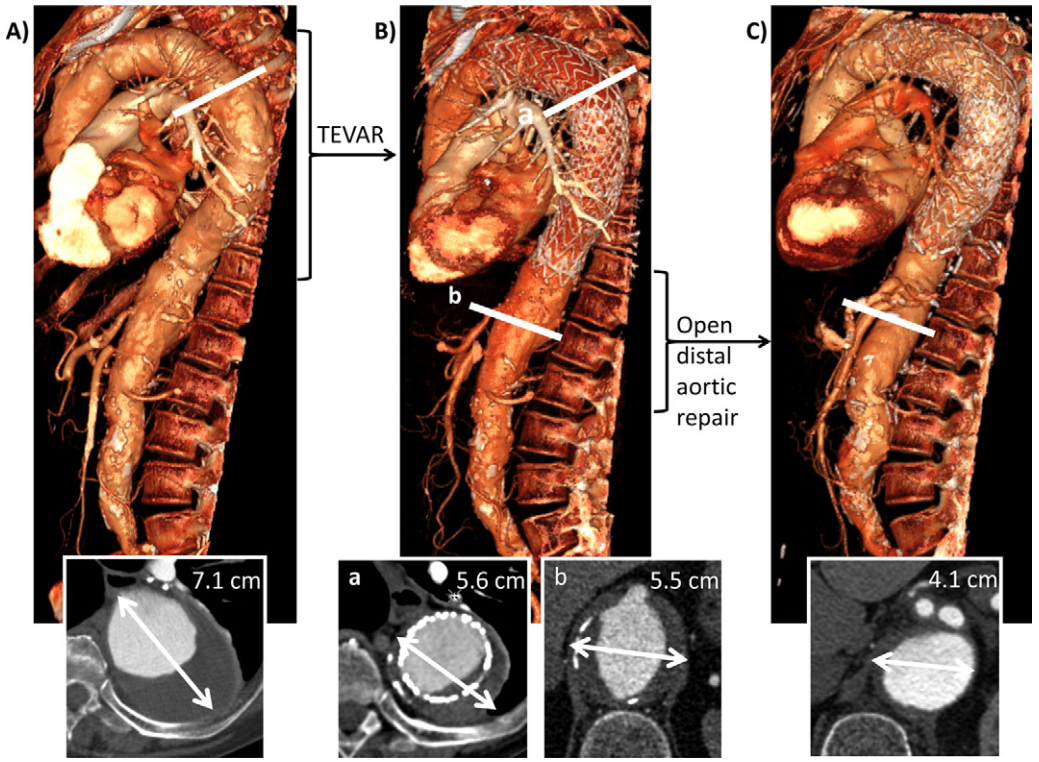

Fig 1. Approach to staged hybrid thoracic endovascular aneurysm repair (*TEVAR*)-open surgery (OS) repair for extensive thoracoabdominal aortic aneurysms. Three-dimensional reconstructions from computed tomography (CT) angiography are shown with sample cross-sectional CT images shown below, corresponding to the level of the *white line* in the aortic CT reconstructions. **A,** A patient presented with a 7.1-cm extent II thoracoabdominal aortic aneurysm secondary to a penetrating aortic ulcer that was treated initially with proximal TEVAR. **B,** Following TEVAR, the proximal aorta remodeled from 7.1 cm to 5.6 cm (cross-sectional image *a*). However, distal thoracic and abdominal aortic expansion occurred (cross-sectional image *b*), which was treated with open distal aortic repair **(C)**.

TAAAs into extent III/IV TAAAs. The second stage is interval OS for replacement of the distal thoracic and abdominal aorta (staged repair abbreviated as TEVAR-OS; Fig 1). The current study reviewed the morbidity and mortality associated with TEVAR-OS for repair of extensive TAAAs.

METHODS

The study protocol was approved by the University of Virginia Institutional Review Board (# 12020) with waiver of informed consent.

Patient selection. A retrospective review of a prospectively maintained database was conducted of patients who underwent staged, hybrid TAAA repair with TEVAR performed at the index operation, followed by OS, between July 2007 and March 2012 at the University of Virginia. Elective and emergency cases were included. Patients were excluded if OS preceded endograft placement, the endograft was removed during OS, or the graft placed during OS was not contiguous with the endovascular stent graft.

Ten patients were identified. Patient characteristics were reviewed and are listed in Table I. Chronic renal insufficiency was defined as a glomerular filtration rate

Table I. Characteristics of the 10 study patients

Characteristic	*Mean ± SD or No. (%)*
Age, years	48 ± 20
Male sex	6 (60)
Hypertension	8 (80)
Current tobacco use	5 (50)
Hyperlipidemia	4 (40)
COPD	2 (20)
Chronic renal insufficiency	2 (20)
Obesity	2 (20)
Diabetes mellitus	1 (10)
Marfan syndrome	3 (30)
Body mass index, kg/m^2	28.3 ± 5.0
Baseline renal function	
Serum creatinine, mg/dL	1.1 ± 0.3
Estimated GFR, mL/min/1.73 m^2	76 ± 26
Crawford extent, %	
Extent II	9 (90)
Extent I	1 (10)
Maximum TAAA diameter, cm	5.7 ± 0.9

COPD, Chronic obstructive pulmonary disease; *GFR,* glomerular filtration rate; *SD,* standard deviation; *TAAA,* thoracoabdominal aortic aneurysm.

(GFR) <60 mL/min/1.73 m^2 for at least 3 months, corresponding with stage 3 insufficiency or higher according to National Kidney Foundation Disease Outcomes Quality Initiative guidelines.[12] Obesity was defined as a body mass index >30 kg/m^2.

The Crawford classification[13] was used to determine the extent of TAAA disease. The definition of Crawford TAAA extents are:

- Extent I: from the origin of the left subclavian artery to the suprarenal abdominal aorta;
- Extent II: from the origin of the left subclavian artery involving most of the infrarenal abdominal aorta;
- Extent III: from the midthoracic aorta to the infrarenal abdominal aorta; and
- Extent IV: involving the suprarenal abdominal aorta but confined inferior to the diaphragm.

Death and spinal cord ischemia were the primary end points reviewed. Secondary end points included cardiac, pulmonary, and renal morbidity after the endograft or OS procedure, including the need for reintervention. Acute kidney injury was defined as a decrease in GFR by 50% or doubling of baseline serum creatinine levels, according to RIFLE (Risk, Injury, Failure, Loss; End-stage renal disease) criteria.[14] Statistical analysis was performed using SPSS 20.0 software (SPSS Inc, Chicago, Ill) with $\alpha = 0.05$. Differences within the patient cohort were compared using the Student *t*-test.

Staged hybrid repair

Endovascular technique. Patients either presented as an emergency after acute type B dissection or as an elective case for chronic TAAA evaluation. Elective patients underwent a full preoperative workup, including risk factor modification and medical optimization. After careful review of the patient's comorbidities and TAAA etiology, TEVAR was considered first-line treatment.

If the origin of the dissection flap occurred ≤15 mm of the origin of the left subclavian artery, a left common carotid-to-left subclavian artery bypass was performed (five of 10 patients) 1 day before TEVAR to extend the proximal landing zone. After the carotid-to-subclavian artery bypass, patients received dextran-40 infusions for temporary anticoagulation until TEVAR was completed. The left subclavian artery was not ligated during carotid-to-subclavian artery bypass to allow possible left brachial artery access to guide TEVAR placement. Before TEVAR, spinal drains were placed prophylactically in seven of 10 patients.

TEVAR was performed in standard fashion, and multiple stents were required in nine patients with ~5 cm overlap between stented sections. Goal TEVAR coverage was as extensive as possible, with approximate aortic coverage from the level of the left subclavian artery origin to the level of the celiac artery or large thoracic spinal arteries in the distal thoracic aorta. In patients with dissection, retrograde filling of the false lumen from distal fenestrations in the abdominal aorta was common (Fig 2). If a left carotid-to-subclavian artery bypass was performed, the left subclavian artery was coil embolized after TEVAR.

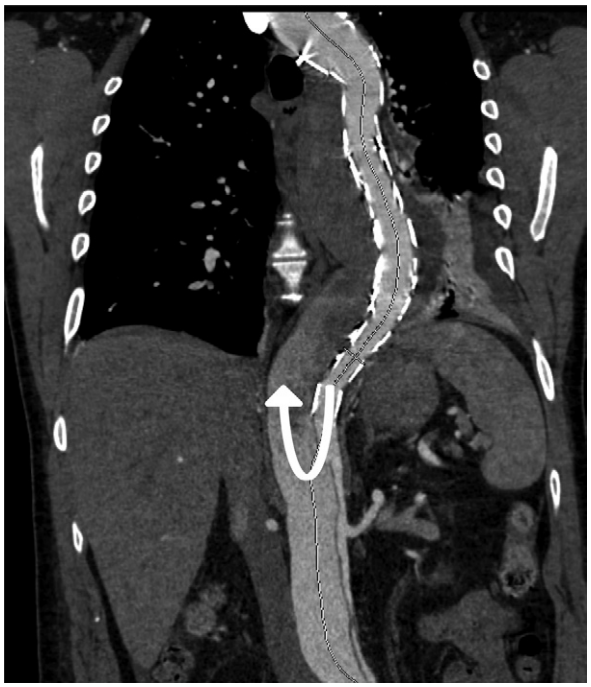

Fig 2. Placement of thoracic endovascular aneurysm repair (TEVAR) from the left subclavian artery origin with persistent perfusion (*white arrow*) in the false lumen from a distal fenestration.

Surveillance. Patients underwent computed tomography (CT) angiography of the chest, abdomen, and pelvis between day 1 to 5 after stent placement to evaluate stent position, endoleaks, and aortic dimensions. Patients were then monitored closely in the clinic with visits every 3 to 6 months, and CT angiography performed at 1 month, 6 months, 1 year, and then annually. A licensed radiologist and an attending surgeon reviewed all imaging studies. Proximal aortic remodeling and enlargement of the distal TAAA near the terminus of the stent was expected from continued aneurysm degeneration (Fig 1, *B*).

Open distal TAAA repair technique. Indications for open repair of the distal TAAA included size >5.5 cm, compromise of visceral perfusion, or rapid expansion of the aneurysm >0.5 cm over 6 months. Before open repair, spinal drains were placed prophylactically for cerebrospinal fluid drainage in all patients. Partial cardiopulmonary bypass was used in all distal TAAA repairs. Four of the initial 10 patients underwent left-sided heart cardiopulmonary bypass from the inferior pulmonary vein to the femoral artery. Six patients subsequently underwent femoral vein-to-femoral artery partial cardiopulmonary bypass with a minibypass circuit due to the following benefits: manipulation of temperature with active rewarming after repair, oxygenation of blood, and pump suction with immediate reperfusion of shed blood.

The midthoracic aorta and underlying endovascular stent were occluded with a Fogarty-Hydragrip (Edwards

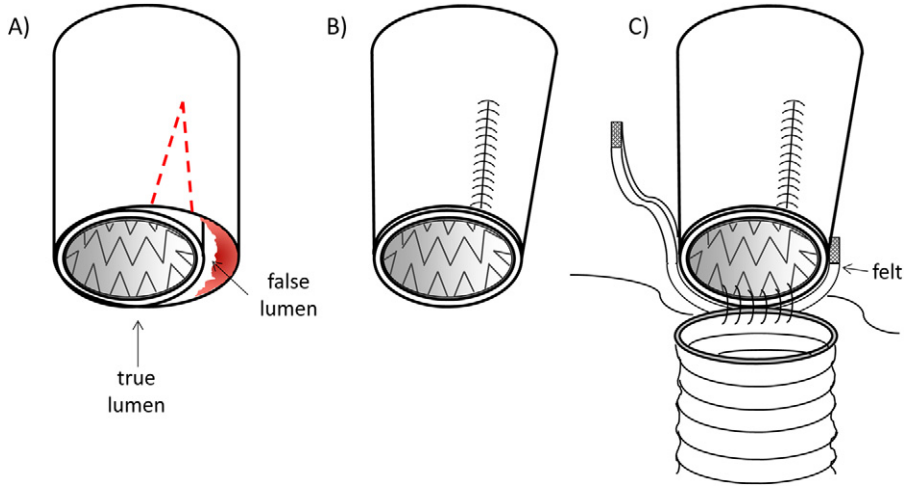

Fig 3. Staged hybrid approach. **A,** Distal thoracic aorta is represented with endograft in the true lumen and thrombus/debris in the false lumen. **B,** The thrombus/debris is removed from the false lumen, dissection septum is divided, and the aortic wall is cut along the *red dashed line* to taper the aortic wall. **C,** The anastomosis is made with an end-to-end attachment of the endograft, tapered aortic wall, and felt reinforcement to the prosthetic graft.

Lifesciences, Irvine, Calif) aortic clamp with no apparent injury to the self-expanding TEVAR graft. After the infrarenal aorta was clamped, the aortic aneurysm sac was entered and visceral arteries were cannulated with sinus catheters from the bypass system to allow visceral perfusion during prolonged aortic occlusion (two of 10). If the infrarenal abdominal aorta was not severely diseased, the distal aortic clamp was initially placed across the supraceliac aorta, allowing retrograde visceral perfusion from the bypass circuit. At the time of the distal anastomosis, the clamp was temporarily moved to the infrarenal aorta with minimal visceral ischemic time.

The thoracic aorta and underlying endograft were divided together, and wire cutters were frequently required to divide the endograft. The aortic lumen was cleared of thrombus and debris, and the dissection septum was divided proximally for ~3 to 5 cm to allow full endograft expansion (Fig 3). The thoracic aorta was tapered to closely approximate the endograft diameter. The proximal anastomosis was performed, attaching the new Dacron graft directly to the endograft, tapered aortic wall, and circumferential felt reinforcement. Involved visceral vessels were anastomosed end-to-end with graft branches from a multibranch aortic graft or as an inclusion patch to the main aortic graft. Large intercostal vessels were preserved and reimplanted into the graft or bypassed with a short 6-mm Dacron graft attached to the aortic graft.

RESULTS

Patient characteristics. Ten patients (60% men) underwent staged hybrid approach with TEVAR-OS between July 2007 and March 2012. Average age was 48 years old (range, 23-76). The most common TAAA etiology was chronic aortic degeneration from chronic dissection in five patients and penetrating aortic ulcer in two patients. Three patients presented with symptomatic acute dissections and subsequently underwent urgent repair. All patients had extensive TAAAs, with nine having Crawford extent II and one patient having a Crawford extent I TAAA. During the study period, 63 isolated TEVARs were performed for thoracic aortic dissections that did not require interval OS.

Hypertension was the most common risk factor (80%), followed by current tobacco use (50%), hyperlipidemia (40%), and Marfan syndrome (30%; Table I). On average, patients with Marfan syndrome underwent TEVAR-OS repair at a younger age (31.6 vs 60.4 years old; $P = .021$).

The median interval between endovascular stent placement and open repair was 14 weeks (range, 13 days-2.0 years). At the time of distal open repair, there were nine extent III TAAAs and one extent IV TAAA. Median follow-up time from TEVAR placement was 70 weeks (range, 13 weeks-4.6 years), and median follow-up after completion of the open distal TAAA repair was 35 weeks (range, 6 weeks-2.2 years).

TEVAR placement. Prophylactic spinal drains were placed before TEVAR in seven patients. Four of the 10 TEVARs were performed entirely percutaneously, and six patients required femoral or iliac artery exposure. Open exposure was more frequent in the earlier patients and in patients with severe femoral artery disease requiring iliac artery access. TEVAR types and sizes are reported in Table II. Multiple stents were used in 90% of patients for goal coverage of most of the thoracic aorta to the celiac origin.

Complications and reinterventions after TEVAR are listed in Table III. Endoleaks occurred in 50% of the patients, and all were treated endovascularly or resolved spontaneously. With the exception of one late type II endoleak seen on aortography immediately after TEVAR placement, four of the five endoleaks were diagnosed on the initial postoperative surveillance CT angiography.

Table II. Thoracic endovascular aneurysm repair stent types and sizes used

Patient	*Stent type (sizes, mm)*
1	Gore TAG ×2 (40 × 200, 40 × 150)
2	Gore TAG ×4 (31 × 150, 31 × 150, 31 × 100, 31 × 100)
3	Gore TAG ×2 (40 × 200, 40 × 150)
4	Cook Zenith TX2 (34 × 152), Gore TAG ×2 (34 × 200, 34 × 150)
5	Gore TAG (37 × 150)
6	Cook Zenith TX2 ×2 (38-34 × 202 tapered, 36 × 202)
7	Gore TAG ×3 (28 × 150, 28 × 100, 28 × 100)
8	Gore TAG ×3 (28 × 150, 28 × 150, 28 × 150)
9	Cook Zenith TX2 × 2 (32-28 × 200 tapered, 28 × 140)
10	Cook Zenith TX2 × 2 (32 × 200, 34 × 202)

Other complications included three pleural effusions occurring within the first 3 days after TEVAR that were treated with pigtail chest tube drainage. In addition, one patient developed new-onset transient atrial fibrillation that was treated with rate-controlling medications. One patient developed transient acute kidney injury after TEVAR following two contrast infusions with additional contrast administered for a type Ib endoleak repair 5 days after initial TEVAR placement. Importantly, there was no perioperative mortality or evidence of spinal cord ischemia.

Most patients were discharged home following TEVAR and underwent close outpatient surveillance. However, two patients required open distal repair before discharge, both from rapid expansion of the distal thoracic aorta. One patient with rapid expansion had new-onset chest pain, whereas the other patient had no complaints but a contained aortic rupture was found on the surveillance CT scan. Excluding these two patients, mean postprocedure hospital stay was 5.5 ± 1.9 days.

The proximal aorta remodeled and conformed to the endograft in 90% cases. One patient with Marfan syndrome had degeneration of her ascending aorta and arch, resulting in an ascending aortic aneurysm with dissociation of the stent and aortic wall 3 months after TEVAR and 1 month after interval open repair. She underwent open ascending aortic and arch replacement with the aortic graft anastomosed to the proximal aspect of the TEVAR graft, tapered aortic wall, and felt reinforcement without complication.

A distal seal with the TEVAR was achieved in most patients. However, a distal seal during TEVAR placement could not be achieved in one patient due to dilation of the aorta at the level of the visceral vessels. CT angiography performed the day after TEVAR placement to evaluate the distal thoracic aorta demonstrated a type Ib endoleak. Endovascular extension of the TEVAR was performed, but serial inpatient reimaging studies demonstrated expansion of the distal thoracic aorta. Therefore, after recovery from TEVAR, he underwent open aortic reconstruction during the same hospitalization.

Open aortic replacement. All patients underwent open repair of extent III (n = 9) or IV (n = 1) TAAAs for expansion of the distal aspect of the TAAA that was not covered with TEVAR, with a mean maximum aortic diameter of 6.6 ± 0.9 cm. Lumbar spinal drains were placed preoperatively in all patients for spinal protection. Complications and reinterventions are listed in Table III. Transient acute kidney injury occurred in two patients, with a peak in the serum creatinine level ≤2 days after open repair. Methicillin-sensitive *Staphylococcus aureus* graft infection developed in one patient 11 months after his distal open aortic repair, which required graft excision and replacement with a rifampin-soaked graft. The patient has since done well, with no further evidence of graft or endograft infection during 4 months of follow-up. In one patient, the abdominal aorta distal to the initial Dacron graft expanded 21.5 months after her initial open repair. Abdominal aortic replacement with an additional Dacron graft directly attached to her previous graft was performed without complication.

Average postoperative hospital stay after open repair was 8.5 ± 2.8 days. There were no pulmonary, cardiac, or neurologic complications, and no deaths at 30 days.

A review of the cumulative TEVAR-OS staged procedure showed there were no deaths or evidence of spinal cord ischemia with a median follow-up of 35 weeks (mean, 42 weeks). No chronic renal insufficiency was precipitated by TEVAR-OS repair, and patients with baseline renal insufficiency had similar trends in their serum creatinine levels compared with patients without renal insufficiency after TEVAR ($P = .634$) and after OS ($P = .402$).

DISCUSSION

Open repair of extensive TAAAs is associated with significant risk of paraplegia and death. The mortality rate after repair of extent II TAAAs ranges from 10% to 42%, and spinal cord ischemia occurs in 7% to 32%.[8] However, open repairs of less extensive TAAAs have decreased rates of mortality and spinal cord ischemia, with open extent III repair having a 9% risk of spinal cord ischemia and extent IV TAAA repair associated with a 1.5% risk of spinal cord ischemia.[7] We have described a method using proximal TEVAR to convert extent II TAAAs to extent III/IV TAAAs amenable to open repair. The current study suggests that staged hybrid repair of extensive TAAAs with TEVAR-OS is safe and appears effective as an alternative to traditional open repair. In our experience to date, there has been no mortality or spinal cord ischemia and no permanent cardiac, pulmonary, or renal complications.

The expected course during the TEVAR-OS procedure was for the proximal thoracic aorta to remodel after TEVAR placement. Distal thoracic aortic enlargement was anticipated from perfusion of the false lumen through distal fenestrations in cases of dissection or from continued degenerative disease. Therefore, patients were closely monitored with frequent cross-sectional imaging to evaluate changes in aortic diameter over time. Continued surveillance remains necessary after open repair because further

Table III. Outcomes after thoracic endovascular aneurysm repair (*TEVAR*) and graft placement

	TEVAR		*Open graft*	
Patient	*Complication*	*Reintervention*	*Complication*	*Reintervention*
1	Atrial fibrillation (POD 2)	None	A: Left femoral artery dissection, repaired intraoperatively B: Distal extension of AAA (19 months post-op)	A: None B: Open AAA repair (21.5 months post-op)
2	None	None	None	None
3	A: Left pleural effusion (POD 1) B: Type II endoleak, transient (POD 0)	A: Left pigtail chest tube B: None	AKI (POD 1)	None
4	Left pleural effusion (POD 1)	Left pigtail chest tube	None	None
5	None	None	Infected graft with MSSA causing pseudoaneurysm at distal anastomosis (11 months after open graft)	Excision of infected graft with placement of rifampin-soaked multibranch graft
6	Type IA endoleak, small (POD 4)	Angiographic embolization of tract (POD 36)	None	None
7	A: Type IB endoleak leading to distal contained aortic rupture (POD 1) B: AKI (POD 7) C: Persistent dilation of distal thoracic aorta (POD 16)	A: Distal TEVAR graft extension (POD 5) B: None C: Urgent open TAAA repair (POD 16)	AKI (POD 2)	None
8	None	None	None	None
9	A: Left pleural effusion (POD 3) B: Type II endoleak from LSA (POD 4) C: Persistent dilation of distal thoracic aorta (POD 12)	A: Left pigtail chest tube B: Angiographic embolization of LSA (POD 4) C: Urgent open TAAA repair (POD 13)	None	None
10	Type II endoleak, transient (POD 1)	None	None	None

AAA, Abdominal aortic aneurysm; *AKI,* acute kidney injury; *LSA,* left subclavian artery; *MSSA,* methicillin-sensitive *Staphylococcus aureus*; *POD,* postoperative day; *TAAA,* thoracoabdominal aortic aneurysm.

dilation can occur, as evidenced by two of the 10 patients requiring additional aortic repairs after the TEVAR-OS procedure was completed.

Unknown to our group, a similar staged hybrid repair was previously reported by Mangialardi et al,[15] who performed aortic repairs on five patients with TAAAs after chronic type B aortic dissections. Similar to our experience, they reported no deaths at a mean follow-up of 30 months. However, two of the five patients (40%) in their study had spinal cord ischemia: one patient with paraparesis after TEVAR that resolved with spinal drainage and physical therapy and one patient with permanent paraplegia after open repair. Spinal drains were not prophylactically placed prior to TEVAR. The present study differs because we included a more extensive array of aortic pathology, including chronic type B dissections, acute type B dissections, and penetrating aortic ulcers. Additionally, our study cohort had twice the number of patients, with no evidence of spinal cord ischemia during the 5-year study period.

Repair of extensive TAAAs is a known risk factor for paraplegia from spinal cord ischemia.[16] Decreased spinal cord ischemia has been demonstrated in staged open TAAA repairs in swine models,[17] with ligation of spinal arteries stimulating vascular collateralization.[18] Similarly, patients with previous thoracic aortic surgery tend to have less paraplegia during TAAA repair than those without previous thoracic aortic surgery, suggesting vascular remodeling is stimulated by the first thoracic aortic intervention.[19] A study that compared single-stage open extent II TAAA repairs with two-stage open repair combining extent I repair, followed by open extent III/IV repairs in humans, found single-stage repair was complicated by a 15% permanent spinal cord injury rate, but no spinal cord ischemia occurred in patients undergoing the two-stage open repair.[11]

The present study demonstrates that patients treated with a two-stage TAAA repair with proximal TEVAR, followed by open distal repair, had minimal morbidity, including no spinal cord injury. By staging the TAAA repair, the cumulative spinal ischemic insult was divided over time to allow interval vascular remodeling and collateralization. In addition, care was taken during each stage to limit spinal cord ischemia and maximize spinal perfusion. Spinal drains were frequently used during proximal TEVAR placement. Spinal drains were set to 10 mm Hg and left in place for 48 hours. In patients with increased risk of spinal ischemia, such as diseased internal iliac arteries or multiple sacrificed or covered spinal arteries, spinal drains were left in

place for up to 72 hours. Before removal, the drain was clamped, with frequent neurologic evaluation. If no neurologic change occurred, the drain was removed.

Left carotid artery-to-left subclavian artery bypasses were performed if the left subclavian origin was covered by TEVAR to ensure continued perfusion of the left vertebral artery. Retrograde filling of the false lumen of the aortic dissection was common and provided perfusion to spinal arteries arising from the false lumen. During open repair, spinal drains were used in all patients. Additionally, partial cardiopulmonary bypass was utilized to provide perfusion to internal iliac arteries with spinal collaterals. Lastly, large intercostal vessels were identified during the open repair and reimplanted to the graft. After TEVAR and open aortic repair, mean arterial pressures were kept >85 mm Hg for 48 hours.

An alternative hybrid approach to extensive TAAAs using visceral debranching, followed by aortic endograft, was first reported by Quiñones-Baldrich et al[20] in 1999 and has gained popularity for being a less invasive approach. In the visceral hybrid repair, the celiac, superior mesenteric, and bilateral renal arteries are perfused in retrograde fashion from the iliac arteries, followed by endograft exclusion of the aneurysm. Visceral debranching, followed by TEVAR, does not require a thoracotomy and may therefore be associated with decreased postoperative pain and pulmonary complications.

However, visceral hybrid repair carries a significant risk of perioperative morbidity. Resch et al[21] reported a 31% incidence of spinal cord ischemia and 23% perioperative mortality. Visceral hybrid TAAA repair is frequently used for higher-risk patients[22] and may be performed as a combined procedure or in two stages. The combined procedure has the benefit of being performed during one hospital stay but carries an increased risk of renal injury, up to 60%.[23] The staged procedure is associated with decreased renal dysfunction but requires the patient to return for a second procedure after open visceral debranching. In the series by Lin et al,[23] 19% of patients did not return for the endovascular portion of the hybrid procedure because of anxiety or pain from the first procedure or because of interval rupture of the aneurysm.

In the current study, TEVAR is the first procedure to be performed and therefore addresses the underlying TAAA etiology. Addressing the cause of the TAAA may decrease the risk of interval rupture. In addition, patient compliance with TEVAR-OS may be increased because the first-stage TEVAR is minimally invasive and typically not associated with significant postoperative pain or anxiety.

The current study is limited by the small patient cohort and is therefore underpowered to assess the actual risks of death and spinal cord ischemia after staged TEVAR-OS. Furthermore, there was no prospective comparison with open repair or visceral debranching. Ideally, TEVAR-OS would be compared with open repair and visceral debranching in a large, randomized, prospective study.

Follow-up was a median of 35 weeks (range, 6 weeks-2.2 years), and continued analysis will be required to determine long-term outcomes. The rate of endoleaks after proximal TEVAR was high, with endoleaks present in 50% of the patients; however, two of these endoleaks were transient type II endoleaks that resolved spontaneously.

CONCLUSIONS

Staged hybrid repair of extensive TAAAs with proximal TEVAR, followed by interval open distal TAAA repair, can be performed with minimal morbidity and appears to be an acceptable alternative approach for the treatment of extensive TAAAs. Most importantly, it is associated with less mortality and spinal cord ischemia than is traditionally associated with extensive TAAA repair.

AUTHOR CONTRIBUTIONS

Conception and design: WJ, GU, JK
Analysis and interpretation: WJ, GU, JK
Data collection: WJ, JK
Writing the article: WJ, GU, JK
Critical revision of the article: WJ, GU, MT, KC, GA, JK
Final approval of the article: WJ, GU, MT, KC, GA, JK
Statistical analysis: WJ
Obtained funding: GU, GA, JK
Overall responsibility: JK

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